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PROBABILITY OF EMERGENCE OF CONFLICT SITUATION DURING PROBLEMATIC TURNING ON INTERSECTION

PRAVDĚPODOBNOST VZNIKU KONFLIKTNÍ SITUACE PŘI PROBLEMATICKÉM ODBOČOVÁNÍ NA KŘIŽOVATCE

Abstract

The paper deals with problems of determining of probability of emergence of selected conflict situation on level intersection. Attention is aimed to the situations which can emergence by the evaluation of inappropriately designed building elements of intersection. The video analysis of conflict situations is use for detection the type and frequency of conflict situations.

Abstrakt

Článek se zabývá problematikou určení pravděpodobnosti vzniku vybraného typu konfliktní situace na úrovňové křižovatce. Pozornost je zaměřena na situace, které mohou vzniknout při hodnocení nevhodně navržených stavebních prvcích křižovatky. Pro zjištění typu a četnosti dané konfliktní situace je využita videoanalýza konfliktních situací.

1 INTRODUCTION

The probability of emergence of conflict situation is very great in present traffic. Conflict situation can be caused by driver, outside factors, breakdown of vehicle or by inappropriately designed road.

The conflict situation can be described by the symbol which includes three parts ([1], [2]):

- one number – description of participants of conflict situation, e.g. 1 = pedestrian, 2 = car, 4 = pedestrian and car, 6 = two or more cars, 9 = other (one cyclist, cyclist and car etc.),
- one or more letters – description of source of conflict situation, e.g. $j_ř$ = ride wrong turning lane, n = violation of rule "yield to ...", g = giving priority against rule etc.,
- one number – description of seriousness of conflict situation:
    - the 1st level – potential conflict situations,
    - the 2nd level – conflict situations when one or more participants are restricted,
    - the 3rd level – conflict situations when one or more participants are endangered,
    - the 4th level – traffic accident.

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2 DESCRIPTION OF INTERSECTION AND CONFLICT SITUATIONS

There was monitored the level intersection on Průběžná street in Ostrava-city (see Fig. 1). The major street (legs B and D) has the turning lanes. The leg C has pedestrian crossing with refuge island.

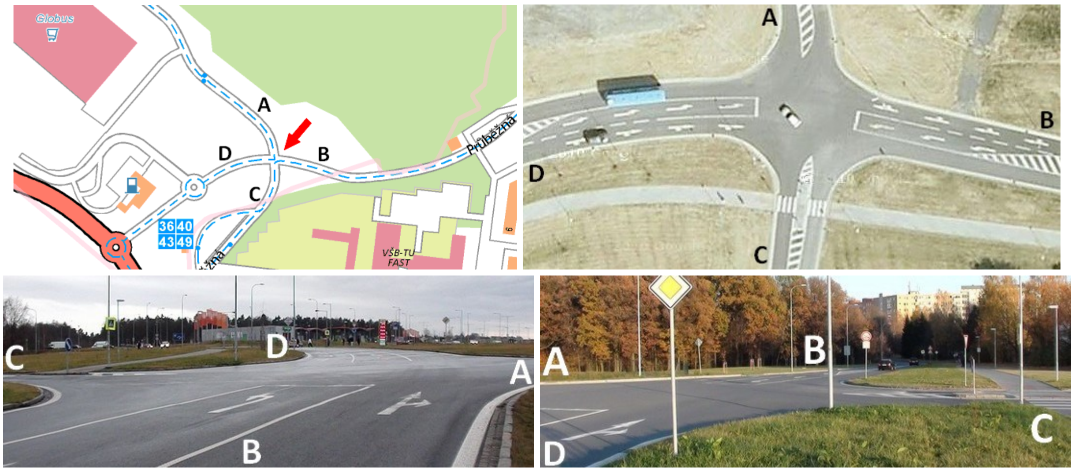

Fig. 1 Monitored intersection.

Following conflict situations were monitored on this intersection: ride by wrong turning lane, ride to opposite lane, mounting on curbs of corners or refuge island etc. This article deals with the first conflict situation, i.e. ride wrong turning lane (2jř1 or 6jř2), when the buses (which are turning left from leg B to leg C) have problem with too narrow lane between refuge island and curb of corner on leg C. The driver of this bus must drive running lane instead of turning lane (see Fig. 2).

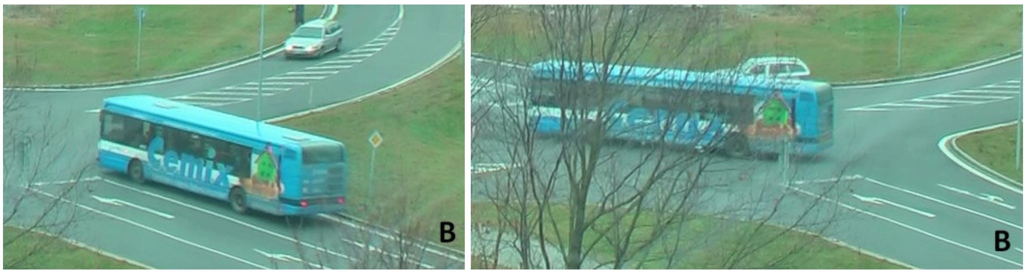

Fig. 2 Conflict situation 2jř1.

There are 17 these conflict situations on monitored entry from 29 of all buses which was turning from B to C). Probability of emergence of this situation is p = 0.5862. We can make some probability calculations (always for buses turning from B to C). For example: probability, that from n following buses x will go by wrong lane, is (according to binomial distribution):

$$P(X = x) = \binom{n}{x} p^x (1-p)^{n-x} \qquad (1)$$

where $n = 1, 2, \ldots; 0 < p < 1$ and $x = 0, 1, 2, \ldots, n$

and where:

$$\binom{n}{x} = \frac{n!}{x!\,(n-x)!} \tag{2}$$

and where for $n \geq 0$:

$$n! = 1 * 2 * \ldots * n = \prod_{k=1}^{n} k \tag{3}$$

For example for n = 10 and x = 5 (Tab. 1 shows all values for n = 1, 2, …, 10):

$$P(5) = \binom{10}{5} 0.5861^5 \, (1 - 0.5861)^{10-5} = 0.2116 \tag{4}$$

Tab. 1 The probability according to binomial distribution for p = 0.5862.

P (x)		***n***									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
x	**0**	**0.4138**	0.1712	0.0709	0.0293	0.0121	0.0050	0.0021	0.0009	0.0004	0.0001
	1	**0.5862**	0.4851	0.3011	0.1661	0.0859	0.0427	0.0206	0.0097	0.0045	0.0021
	2		0.3436	0.4266	0.3530	0.2435	0.1511	0.0875	0.0483	0.0257	0.0133
	3			0.2014	0.3334	0.3449	0.2855	0.2067	0.1369	0.0849	0.0502
	4				0.1181	0.2443	0.3033	0.2928	0.2423	0.1805	0.1245
	5					0.0692	0.1719	0.2489	0.2747	0.2557	**0.2116**
	6						0.0406	0.1175	0.1945	0.2415	0.2498
	7							0.0238	0.0787	0.1466	0.2022
	8								0.0139	0.0519	0.1074
	9									0.0082	0.0338
	10										0.0048

The probability, that bang following bus will go by wrong lane, is (according to Bernoulli distribution):

$$P(X = 0) = 1 - p = 1 - 0.5862 = 0.4138 \tag{5}$$

$$P(X = 1) = p = 0.5862 \tag{6}$$

These values correspond to binomial distribution pro n = 1 and x = 0 or x = 1 (see Tab. 1 – column for n = 1).

The probability, that for emergence of the first wrong turning from B to C we need x buses, is (according to geometric distribution):

$$P(X = x) = p\,(1 - p)^{x-1} \tag{7}$$

For example for x = 5 (Tab. 2 shows all values for x = 1, 2, …, 10):

$$P(5) = 0.5862\,(1 - 0.5862)^{5-1} = 0.0172 \tag{8}$$

In other words: the fifth bus will turn by wrong lane with probability 0.0172.

Tab. 2 The probability according to geometric distribution for $p = 0.5862$.

x	P(x)
1	0.5862
2	0.2426
3	0.1004
4	0.0415
5	**0.0172**
6	0.0071
7	0.0029
8	0.0012
9	0.0005
10	0.0002

Tab. 3 The probability according to negative binomial distribution for $p = 0.5862$ and $x = 4$.

n	P(n)
4	0.1181
5	0.1955
6	0.2022
7	0.1673
8	0.1212
9	0.0802
10	**0.0498**
11	0.0294
12	0.0167
13	0.0092
14	0.0050
15	0.0026
16	0.0014
17	0.0007
18	0.0003
19	0.0002
20	0.0001

The probability, that we need x buses for emergence of x wrong turning, is (according to negative binomial distribution):

$$P(X = n) = \binom{n-1}{x-1} p^x (1-p)^{n-x} \tag{9}$$

where $x = 1, 2, \ldots$ and $0 < p < 1$.

For example for $x = 4$ and $n = 10$ (Tab. 3 shows all values for $n = 4, 5, \ldots, 20$):

$$P(10) = \binom{10-1}{4-1} 0.5862^4 (1-0.5862)^{10-4} = 0.0489 \tag{10}$$

In other words: the fourth bus turning by wrong lane will be with probability 0.0489 the tenth bus turning form leg B to leg C.

3 CAPACITY CALCULATIONS

For our example only the capacity of entry B will shown. This capacity is calculated by TP 188 [3]. Running direction from leg B to C (left) we can mark as Traffic flow 1 (for our example with volume I_1 = 37 veh/h), direction from leg B to D (ahead) as Traffic flow 2 (I_2 = 118 veh/h) and direction from leg B to A (right) as Traffic flow 3 (I_3 = 39 veh/h).

Capacity of traffic flow 2 and 3 (common traffic lane) is $C_{2,3}$ = 1800 veh/h [3]. The reserve of capacity of this lane is:

$$\text{Re}z_{2,3} = C_{2,3} - (I_2 + I_3) = 1643\ veh/h \tag{11}$$

Capacity of traffic flow 1 (left turning) is:

$$C_1 = G_1 = \frac{3600}{t_f}.e^{-\frac{I_H}{3600}\left(t_g - \frac{t_f}{2}\right)} = 1232\ veh/h \tag{12}$$

where:

C_1 – capacity of lane for left turning [veh/h],
G_1 – basic capacity of lane for left turning [veh/h],
I_H – adjudicate volume of superordinate traffic flows [veh/h] (= 131 veh/h),
t_g – critical gap [s] (=4,5 s),
t_f – follow gap [s] (= 2,6 s).

The reserve of capacity is then:

$$\text{Re}z_1 = C_1 - I_1 = 1195\ veh/h \tag{13}$$

Total reserve of capacity is then 2838 veh/h.

Capacity of entry B will be changed, if the entry has only one common traffic lane for traffic flow 1, 2 and 3. This capacity is then:

$$C_{1,2,3} = \min\left\{\begin{matrix} \dfrac{I_1 + I_2 + I_3}{a_{v1} + a_{v2} + a_{v3}} \\ 1800 \end{matrix}\right\} = \min\left\{\begin{matrix} \dfrac{I_1 + I_2 + I_3}{\dfrac{I_1}{C_1} + \dfrac{I_2}{C_2} + \dfrac{I_3}{C_3}} \\ 1800 \end{matrix}\right\} = 1654\ veh/h \tag{14}$$

The reserve of capacity is then:

$$\text{Re}z_{1,2,3} = C_{1,2,3} - (I_1 + I_2 + I_3) = 1461\ veh/h \tag{15}$$

The reserve of capacity for common traffic lane is about half than reserve of capacity for separate lane. We can say that the reserve of capacity of entry B is between 1461 and 2838 veh/h.

3 CONCLUSIONS

The calculations above mentioned are certainly only theoretic. It's always necessary to compare its reality with real traffic on real intersection (and to calculate with probability of emergence of conflict situations) or with simulation model which was made by special software.

Modeling and simulation are main tools in many areas of human activities. It can allow increase effectively of processes and activities in designing, development and not only in engineering and technology areas, also in service and economic areas [4] – it also applies to transport.

The video analysis of conflict situations is very appropriate method for detection of the type and number of conflict situations which are caused by inappropriately designed building elements of intersection (see for example [2] and [5]). This methodology can be appropriate use also by auditor during safety inspection of road according to law No. 13/1997 [6].

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